N88-17696

Dr. S. Staniek, Dr. G. Otto, Dr. J. Dōpkess *
DFVLR, D-5000 Kōln 90, *MBB/ERNO, D-2800 Bremen, FRG

TEN PAST AND TEN FUTURE GAS/MAUS-PAYLOADS

Abstract
MAUS - a German acronym for materials science autonomous experiments - is one out of a series of flight opportunities which the Space Program of the Federal Republic of Germany offers to scientists from the disciplines of materials research and processing for performing materials science investgations under micro-gravity conditions. Up to now ten MAUS experiments were flown which were dealing with the following scientific topics: decomposition of binary alloys with miscibility gap in the liquid state, interaction of a solidification front with dispersed particles, critical marangoni number, investigation of the magnetic compound MnBi, shrinkage of gas bubbles in glas melts and slip casting.
The ten future experiments are partly reflights with modification of the scientific objectives as well as new experiments in the fields of chemical reactions, heat-transfer, glass technology and Ostwald-ripening.
Looking to ten flown payloads the peculiarities of instrument technology in GAS-cans and its evolution will be discussed with emphasis on structure, electronics and thermal design. A typical modern payload using 100 % of the resources will be presented.

1. Programmatic aspects of the MAUS-Project

In 1979 the German Minister for Research and Technology (BMFT) signed 25 GAS-LSA`s and established the MAUS-GAS program. The MAUS-project management was assigned to the German Aerospace Research Establishment (DFVLR), and MBB/ERNO was selected as the industrial prime contractor. The programmatic concept of the project is based on 2 missions a year of dual MAUS-payloads in the GAS-program. To achieve this goal the MAUS-standard-system has been developed. To assure the feasibility of a multitude of materials science experiments the design of this system was based on the requirements profiles of 25 experi-ments. With the provision of 10 flight units of the MAUS-standard-system the possibility for accomodation of different experiment specific hardware designed by the experimenters themselves is given.

Scientific Objectives and Results

The ten experiments flown up to date within the MAUS Project cover a wide range of topics from the area of material sciences. Essential scientific results have been obtained which either stand on their own or serve as supportive data for Spacelab experiments. A listing of the experiment titles and the resonsible Principal Investigators is given in Table 1.

Table 1: Summary of MAUS Payloads Flown

MAUS Mission	Payload No.	Shuttle Mission	Launch Date	Carrier	Experiment Title	Primary Investig.	Institution
1	1	STS-5	11/11/82	GAS	Verification Payload	Dr. Otto	DFVLR Köln
2	2	STS-7	06/18/83	SPAS-01	Critical Marangoni Number	Dr. Schwabe	U. Giessen
2	3			SPAS-01	Alloys of the System Mn-Bi I	Dipl-Ing Pant	Krupp FI Essen
3	4			OSTA-2	Solidification Front	Dr. Klein	DFVLR Köln
3	5			OSTA-2	Metallic Dispersions I	Dr. Otto	DFVLR Köln
3	6			OSTA-2	Metallic Dispersions II	Dr. Otto	DFVLR Köln
4	7	STS-11	02/01/84	SPAS-01A	Slip Casting I	Dr. Schweitzer	MTU München
4	8			SPAS-01A	Gas Bubbles in Glass Melts I	Prof. Frischat	U. Clausthal
5	9	STS-51G	06/17/85	GAS	Alloys of the System Mn-Bi II	Dipl-Ing Pant	Krupp FI Essen
5	10			GAS	Slip Casting II	Dr. Schweitzer	MTU München

Ten payloads for future flights in the Get Away Special Prgram are in various stages of preparation and a listing of the experiment titles and the resonsible Principal Investigators is given in Table 2. A condensed form of the scientific objectives follows below.

Table 2: Summary of MAUS Payloads in Preparation

MAUS Mission	Payload No.	Carrier	Experiment Title	Primary Investig.	Institution
6	11	GAS	Critical Marangoni Convection	Dr. Chun	Univ. Essen
6	12	GAS	Oscillatory Marangoni Convection	Dr. Schwabe	Univ. Giessen
7	13	GAS	Pool Boiling	Prof. Straub	Univ. München
7	14	GAS	Gas Bubbles in Glass Melts	Prof. Frischat	Univ. Clausthal
8	15	GAS	Ostwald Ripening	Dr. Ratke	MPI Stuttgart
8	16	GAS	Reaction Kinetics	Prof. Frischat	Univ. Clausthal
9	17	GAS	Chemical Instabilities	Dr. Bewersdorff Dr. Avnir	DFVLR Köln
9	18	GAS	CO_2 Dissolution in Glass Melts	Prof. Frischat	Univ. Clausthal
10	19, 20	GAS	Interconnected MAUS Payloads	TBD	TBD

Critical Marangoni Convection:

Marangoni convection in this experiment is achieved by a temperature gradient between two circular plates which can also be rotated. The following goals are considered: Documentation of the influence of iso-rotation on the steady and oscillatory Marangoni convection; evaluation of the shape stability of the floating zone configuration during rotation; determination of the influence of higher Marangoni numbers on the hydrodynamic stability of Marangoni convection by variation of the temperature gradient. Convection is made visible in silicone oil by dispersed particles. Observation is by a laser cut technique in a defined plane which is recorded by a movie camera.

Oscillatory Marangoni Convection:

The goal of this experiment is to investigate Marangoni convection and to determine the critical Marangoni number at which the convection becomes oscillatory. Oscillations (about 1 Hz) are observed by means of a thermo-couple within the liquid zone. The material to be investigated is $NaNO_3$. In addition to previous successful MAUS investigations the length of the column will be increased giving access to a different aspect ratio.

Pool Boiling:

Pool Boiling (nucleate boiling) and forced convection are the most effective heat transfer mechanisms. From the many fluid physics phenomena which are observed in boiling kinetic heat and mass transport by evaporation and condensation is independent of gravity. This experiment will lead to a physical separation of the gravity driven parameters and therefore to a better understanding of the boiling process. A platinum wire immersed in Freon 12 will be used to initiate boiling. The bubble behavior will be recorded simultaneously by two cameras with different recording frequencies.

Gas Bubbles in Glass Melts:

Fining is one of the most important processes on technical glass fabrication.The removal of gass bubbles from glass melts can be achieved in two ways: Rising of the bubbles controlled by buoyancy (which is not possible in microgravity) and dissulution by diffusion. The shrinking of a He-bubble at around 1100 ° C was successfully recorded in a previous MAUS experiment. This investigation will be performed at the higher temperature of 1300° C to complement data on the diffusion in a wider temperature range. The convectional influence is expected stronger and a larger difference between earth and space

experiment will result. In a follow-up experiment the objectives will be extended towards technically relevant glasses like the dissolution of CO_2 in silicate glass melts.

Ostwald Ripening:

The phenomenon of Ostwald ripening is represented in a dispersion by growth of larger droplets on the expense of smaller ones. For this kind of studies metallic alloys with a miscibility gap in the liquid state are well suited like the system aluminum-indium. Samples which are already in a dispersed state will be heated into the miscibility gap but not above. With a series of samples Ostwald ripening and related interfacial phenomena will be studied. The experiment will require furnaces with long-term temperature stability and a regulating accuracy of smaller than 1° C.

Reaction Kinetics in Glass Melts:

The interdiffusion between two silicate glasses (potassium and rubidium silicate) and the corrosion behavior of SiO_2 glass by alkali halogenide is observed. Transport mechanisms in glass melts will be derived and a theroretical model for this case defined. Disturbing buoyancy forces are avoided by microgravity conditions.

Chemical Instabilities:

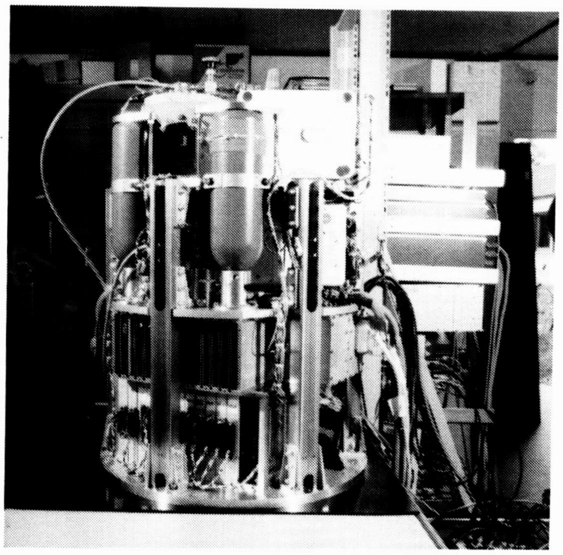
The spontaneous formation of three-dimensional structures may occur in systems far from thermodynamic equilibrium. This process must involve transport of matter by convection and/or diffusion. To clarify the mechanism of pattern formation a space experiment will be performed to exclude gravity driven convection. The photochemical reaction will be activated by ultraviolet light in microgravity and pattern formation with its consecutive development photographed by an optical camera.

Interconnected MAUS Payloads:

In this MAUS 10 mission two containers will be interconnected to transfer data and electrical power. This feature is very important to meet the challenge of future advanced payloads. Preliminary studies in this direction have already been performed. However, the scientific experiments for these missions have not yet been selected.

3. Instrument Technology

The basic design of a MAUS-Payload consists of the standard experiment mounting structure (EMS), the battery (Ag-Zn, Ni-Cd) the standard electronics for experiment control and data acquisition, the housekeeping system, and the experiment hardware including experiment dedicated electronics. The past 10 MAUS-experiments have been flown with this standard configuration, which has been presented in detail in former GAS-Symposia. The experience gained during the past MAUS missions showed that in connection with progress in technology experiments supposed to be accomodated in the Spacelab could well be flown as an outonomous payload in the GAS-program.
As an example of such a complex payload MAUS-payload DG-504 will be presented (Fig. 3.1). The experiment modification needed to suit the requirements of that payload will be discussed.



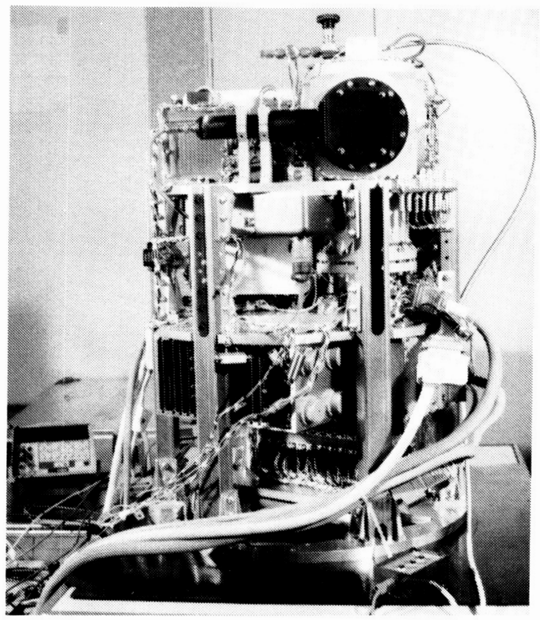


Fig. 3.1: MAUS-Payload DG 504

To reach the scientific goal, this payload requires the following resources (the nominal ones of a standard MAUS-payload are given in parenthesis):

- o Mass: 42.2 kg (20 kg)
- o Energy: 1.36 kWh (1.04 kWh Ag-Zn-battery with 46 cells instead of 80)
- o Command: 26 (16)
- o Data: 24 Mbit (10 Mbit)

The command and data requirements could be fulfilled using one analog output to generate 10 additions and by using thinner tapematerial and reducing tapespeed. The optimized experiment hardware without interface electronics requires almost the total volume available. Thus, the interface electronics could not be accommodated on the experiment platforms. The only solution was to construct a new adapter ring (Fig. 3.2) allowing the accommodation of an interface electronics box containing up to fourteen cassetts of experiment dedicated electronics.
The voltage regulators as well as the clock unit of MAUS experiment DG 504 could not be assembled in one cassette each, if conventional electronic components were used. Therefore, the units were partly manufactured by using SMD (Surface-Mounted-Device) technology resulting in a high packing density especially by applying multilayer techniques. Fig. 3.3 shows the voltage regulator unit.

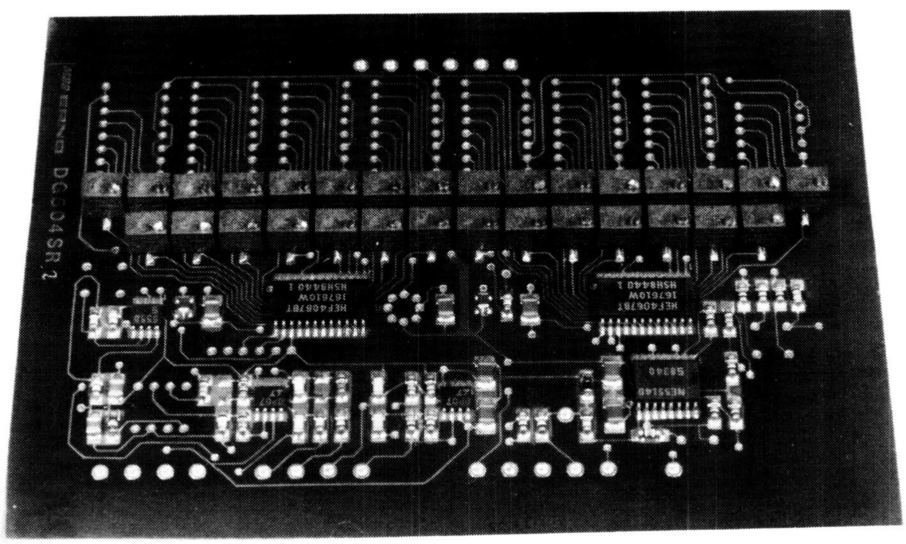


Fig. 3.2: Card with SMD`s

Further advantages of SMD technology are:
- higher mechanical stability concerning vibration and shock
- parasitic capacities and inductivities are drastically reduced

Due to the accomodation of the interface electronics on the new adapter ring, the available space for the battery is reduced to almost 50 %. Consequently the mass available for experiment hardware increases of approximately 12 kg. Further mass reduction of the standard system is achieved by using a dc/dc converter to supply standard electronics as well as by reduction of structure mass, e.g. open spaces in platforms.
These modifications also lead to a reduction of the available energy to almost 50 %. But to perform a reasonable experiment from the scientific point of view 1.36 kWh are needed. The only solution is a change in battery type from Ag-Zn to Li-SO_2 non -rechargeable batteries, both produced by the company SILBER-KRAFT.
Li-SO_2 battery packages have already been manufactured according to the safety requirements of the STS-program (Fig.3.3). The advantages of these batteries are:

- o almost unlimited lifetime (no problem with delays of STS-missions)
- o safety features
  - reverse-save cells
  - diode-quat safety concept
  - temperature / current fuses

- o compared to other battery system
  - low cost of cells
  - high energy / mass ratio

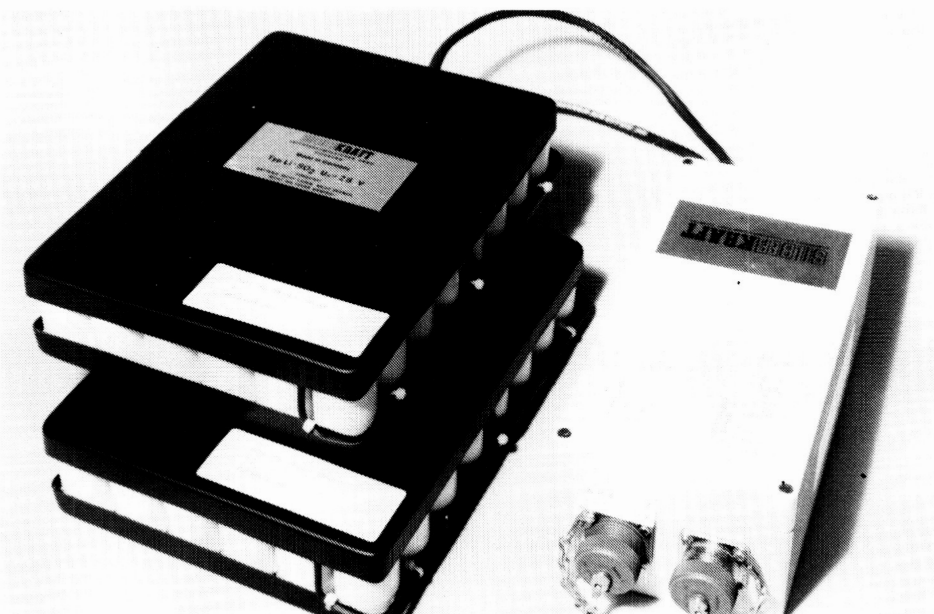


Fig. 3.3 Engineering Model of Li-SO_2 Battery Cell Packages together with the Distribution and Fuse Box.

Up to now, for each up MAUS-payload a thermal analysis has been performed. In a mathematical node-model the thermal properties were imitated. The optimal insulation can be calculated for critical components.

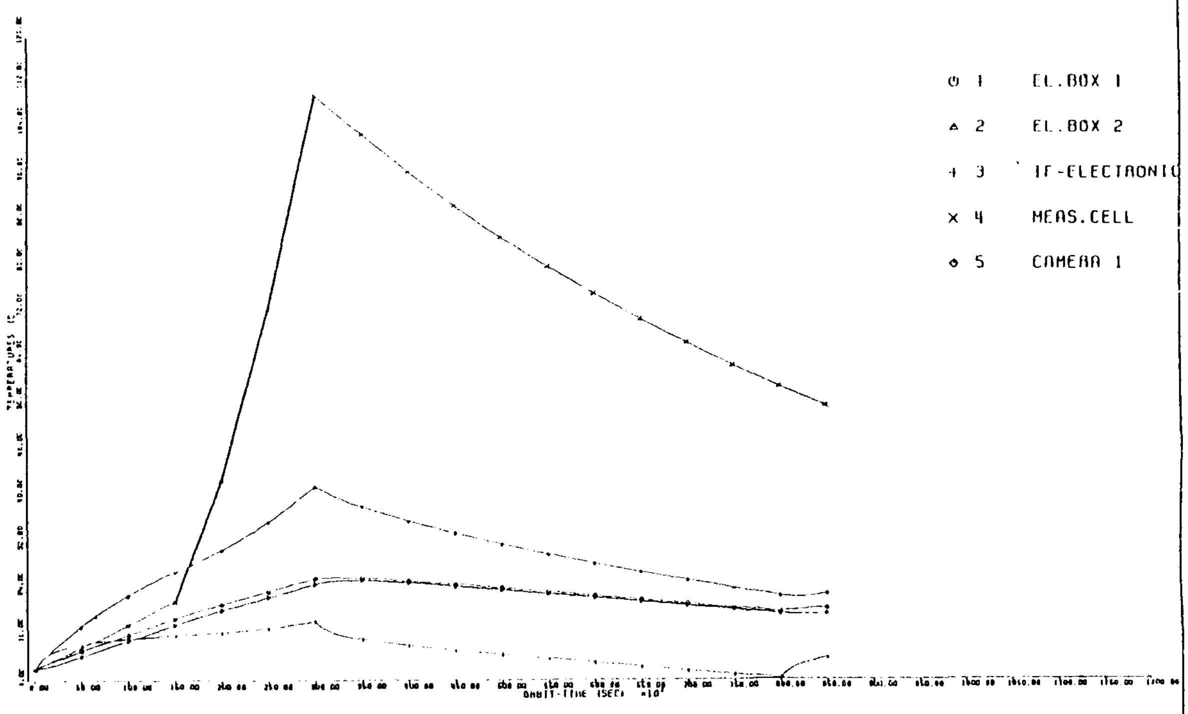


Fig. 3.4: Temperature vs Time, Experiment DG 504

From the ten flown MAUS-payload it turned out that a passive thermal control system was sufficient to meet acceptable temperature values.
MAUS payload DG 324 "Gas Bubbles in Glass Melts" will be reflight of MAUS payload DG 318 but with a different experiment profile (higher temperature, longer duration). With an average power consumption of 300 W for 3.7 hours, the thermal analysis showed that this experiment needs additional thermal equipment to avoid overheating of hardware mounted in the vicinity of the furnace.
Assuming the experiment mounting plate of the GAS-can to be used as a radiator, the heat transport form the upper experiment platform to the radiator has to be increased. A change of the post material from V A-steel to aluminum turned out not to be sufficient. Only the integration of heatpipes can provide the required conductive heat path. The detailed layout of the heat-pipes and further thermal analysis is currently under development.